

FS-045 | Zebra mussels in North America: *The invasion and its implications*

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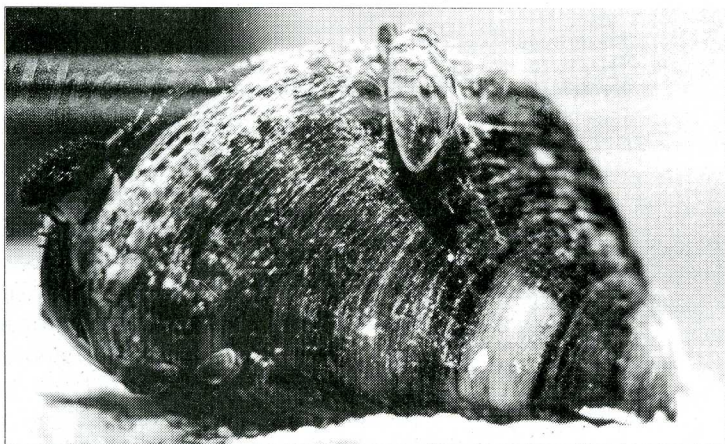
Zebra mussels (*Dreissena polymorpha*) were first discovered in Lake St. Clair in 1988. Within one year, they had colonized the surfaces of nearly every firm object in western Lake Erie. As of December 1993, zebra mussels have been found in all of the Great Lakes and in waterways in 18 states and two provinces. Major river systems that now have zebra mussels include the St. Lawrence Seaway and the Hudson, Illinois, Mississippi, Ohio, Arkansas, and Tennessee Rivers.

Zebra mussels also have been reported in several inland lakes, including Lake Wawasee in Indiana; Hargus Lake and White Star Quarry in Ohio; Kentucky Lake and Dale Hollow Reservoir in Kentucky; at least 10 lakes in Michigan; and Balsam, Rice, and Big Bald Lakes in Ontario.

In 1991, a second species of *Dreissena* was discovered in North America but was only recently identified. Quagga mussels (*Dreissena bugensis*) have been found in the St. Lawrence Seaway, Lake Ontario, Lake Erie, and Saginaw Bay in Lake Huron.

It is not clear when, how far and into which waterways the zebra and quagga mussels will spread. The zebra mussel has spread faster and farther than expected. Its southward spread will likely be limited because of average summer water temperatures above 81 F (27 C). The northward spread might be limited by soils deficient in calcium or by summer water temperatures below 54 F (12 C).¹

Questions about zebra and quagga mussels abound, but finding answers is a difficult task. The following information answers some of the more commonly asked questions about zebra and quagga mussels.



Lloyd Lemmerman

The invasion

Dreissena polymorpha and *Dreissena bugensis* are native to an area in Russia near the Caspian Sea. Canals built during the late 1700s allowed the mussels to spread throughout eastern Europe. During the early 1800s, canals were built across the rest of Europe, which made bulk shipping much easier but also allowed rapid expan-

sion of the zebra mussel's range. By the 1830s, the mussels had covered much of the continent and had invaded Britain.

The introduction of zebra mussels into the Great Lakes appears to have occurred in 1985 or 1986, when one or more transoceanic ships discharged ballast water into Lake St. Clair. The freshwater ballast, picked up in a European port, may have contained zebra mussel larvae and possibly juveniles; or, adult mussels may have been carried in a sheltered, moist environment, such as a sediment-encrusted anchor or chain. The faster speed of today's ships provides exotic species a better chance of surviving the trip across the Atlantic. Being a temperate, freshwater species, the zebra mussels found the plankton-rich Lakes St. Clair and Erie to their liking.

Zebra and quagga mussels

The rapid spread and abundance of both mussels can be partly attributed to their reproductive cycles. A fully mature female mussel may produce up to one million eggs per season. Egg release starts when the water temperature warms to about 54 F (12 C) and continues until the water cools below 54 F. In Lake Erie, spawning may begin as early as May and end as late as October, but it peaks during July and August at water temperatures above 68 F (20 C).

Eggs are fertilized outside the mussel's body and within a few days develop into free-swimming larvae called veligers. Veligers swim by using their hair-like cilia for 3 to 4 weeks, drifting with the currents. If they don't settle onto firm objects in that time, they die; and the vast majority actually suffer this fate. It is estimated that only 1 to 3 percent survive to adulthood. Those that find a hard surface quickly attach and transform into the typical, double-shelled mussel shape; they are then considered to be juveniles.

Mussels become adults when they reach sexual maturity, usually within a year. They grow rapidly, nearly an inch in their first year, adding another 1/2 to 1 inch their second year.

European studies report mussels may live 4 to 6 years. Three years seems to be the maximum life span in Lake Erie, but there is insufficient data to know what to expect in other North American bodies of water.

Zebra mussels generate a tuft of fibers known as a byssus, or byssal threads, from a gland in the foot. The

***Dreissena* arrived in North America and rapidly colonized industrialized, plankton-filled Great Lakes, which support multi-million-dollar sport and commercial fisheries.**

byssus protrudes through the two halves of the shell. These threads attach to hard surfaces with an adhesive secretion that anchors the mussels in place. Small juveniles can actually break away from their attachments and generate new, buoyant threads that allow them to drift again in the currents and find a new surface. Zebra mussels can colonize any firm surface that is not toxic: rock, metal, wood, vinyl, glass, rubber, fiberglass, paper, plants, other mussels—the surface need only be firm. Beds of mussels in some areas of Lake Erie now contain more than 30,000—and sometimes up to 70,000—mussels per square meter.

Zebra mussel colonies show little regard for light intensity; hydrostatic pressure (depth); or even temperature, when it is within a normal environmental range. The life stage most sensitive to low temperature is the veliger stage, and juveniles are more sensitive than adults. All life stages are sensitive to low levels of dissolved oxygen, particularly as temperature increases. Colonies grow rapidly wherever oxygen and particulate food are available and water currents are not too swift (generally less than 6 feet per

Because of its shallow, warm, nutrient-enriched environment, Lake Erie will always support significant populations of zebra and quagga mussels.

second). Thus, colonies are rare in wave-washed zones, except for sheltered nooks and crevices. In most European lakes, the greatest densities of adult mussels occur at depths ranging from 6 to 45 feet.

Zebra mussels can also colonize soft, muddy bottoms when hard objects deposited in or on the mud—such as pieces of native mussel shells—serve as a substrate (base) for settling veligers. As a few mussels begin to grow, they in turn serve as substrate for additional colonization, forming what is known as a *druse*. Quagga mussels can live directly on a muddy or sandy bottom and appear more tolerant of low temperatures and extreme depths than zebra mussels.

Biological and ecological concerns

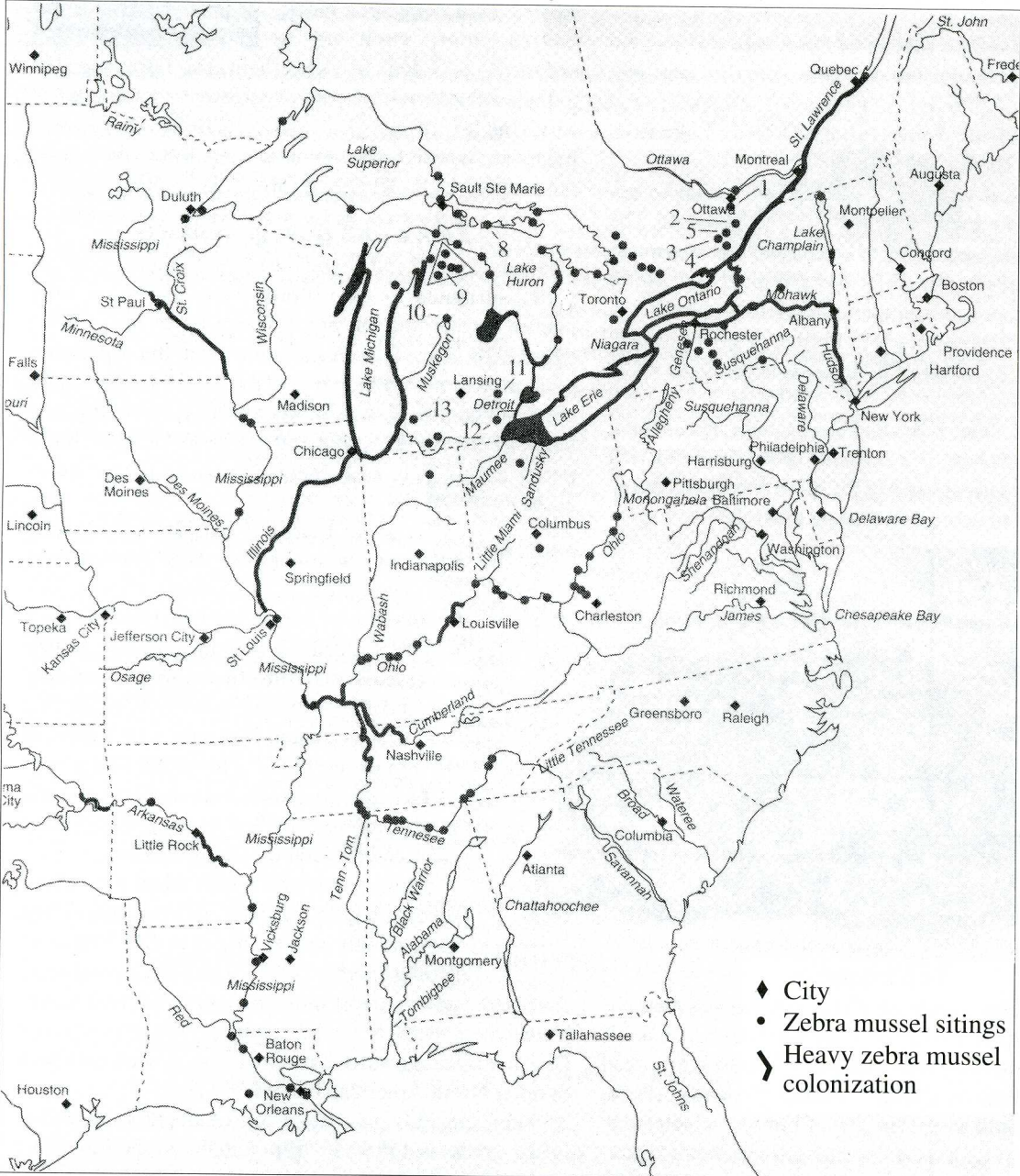
Zebra mussels disrupt the aquatic food chain. Literature reviews suggest that they eat mostly algae in the 15-40 micrometer size range. Each adult mussel, however, is capable of filtering 1 or more liters of water each day. They remove nearly all particulate matter, including phytoplankton and some small forms of zooplankton, including their own veligers. Instead of passing any undesired particulate matter back into the water, mussels bind it with mucous into loose pellets called pseudofeces that are ejected and accumulate among the shells in the colony.

By removing significant amounts of phytoplankton from the water, zebra mussels remove the food source for microscopic zooplankton, which in turn are food for larval and juvenile fishes and other plankton-feeding forage fish. These forage fish support sport and commercial fisheries. This competition for phytoplankton, the base of the food chain, could have a long-term negative impact on Great Lakes fisheries. Observations of the effects of zebra mussel filtration upon the food base for fish communities are still inconclusive.

Most rocky areas in Lake Erie are almost completely covered with mussels several inches deep. In laboratory observation, the accumulation of pseudofeces in these beds creates a foul environment. As waste particles decompose, oxygen is used up, and the pH becomes very acidic. Biologists were initially concerned that such poor environmental conditions could potentially hinder normal egg development of reef-spawning fish (walleye, white bass, and smallmouth bass). However, large hatches of walleye documented in Lake Erie in 1990, 1991, and 1993 suggest that flushing water currents are sufficient to prevent environmental deterioration.

Zebra mussels readily encrust native North American mussels (family

North American range of the zebra mussel as of 15 December 1993.



- ◆ City
- Zebra mussel sightings
- ▮ Heavy zebra mussel colonization

Exotic species are nothing new in the Great Lakes. Scientists believe the sea lamprey led the way back in the 1830s. Since then, scientists have identified 136 plant, fish, and mollusk species that have been introduced.

Uniodidae). In Lakes St. Clair and Erie, heavy fouling by zebra mussels has severely reduced populations of native mussels. Some native mussel species are more tolerant to fouling than others, but even for these resistant species, zebra mussel encrustation leads to reduced energy reserves and vulnerability to other environmental stressors, such as extreme water temperatures, lack of food, or parasites and disease. As zebra mussels spread, biologists are concerned that populations of native mussels will decline, and perhaps some of the rarer species may be completely eliminated.

Zebra mussels apparently have contributed to the improvement of Lake Erie's water clarity, which began with the initiation of the phosphorus abatement programs of the 1970s. Shallow embayments are being recolonized by rooted, aquatic plants, since turbidity no longer shades them out. According to Dr. Ruth Holland Beeton, who conducted research near Stone Laboratory on Lake Erie in the 1970s, before phosphorus abatement programs, water clarity was approximately 3 feet, improved to 6 to 10 feet in the 1980s after a decade of reduced phosphorus inputs, and improved again to 10 to 17 feet in the early 1990s, after zebra mussels colonized the area.

The prodigious filtering of water by zebra mussels may increase

Clear waters do not necessarily mean safe, clean waters. Zebra mussel's activities may make toxic substances available to new organisms in the food chain. Because zebra mussel feces and pseudo-feces stay at the bottom of the lake, zebra mussels transfer plankton to the benthos, where they create a potentially tainted food supply for benthic organisms, such as gammarid amphipods.

human and wildlife exposure to organic pollutants (PCBs and PAHs). Early studies have shown that zebra mussels can rapidly accumulate organic pollutants within their tissues to levels more than 300,000 times greater than concentrations in the environment. They also deposit these pollutants in their pseudofeces. These persistent contaminants can be

passed up the food chain so that any fish or waterfowl consuming zebra mussels will also accumulate these organic pollutants. Likewise, human consumption of these same fish and waterfowl could result in further risk of exposure. The implications for human health are unclear.

Industrial, commercial, and recreational concerns

The zebra mussel's proclivity for hard surfaces located at moderate depths has made water intake structures, such as those used for power and municipal water treatment plants, susceptible to colonization. Since 1989, some plants located in areas of extensive zebra mussel colonization have reported significant reductions in pumping capabilities and occasional shutdowns.

Investigations of zebra mussel control on intake structures have included prechlorination, preheating, electrical shock, and sonic vibrations. Current control methods include prechlorination, ozone, potassium permanganate injection, and sand bed filtration. Prechlorination has been the most common treatment used to date, because it is already approved for use by the Environmental Protection Agency; but it also raises concerns about the toxicity of chlorinated compounds to other aquatic organisms.

Zebra mussels are very sensitive to high temperatures. Some thermal electric plants currently are experimenting with the diversion of waste heat into intake structures to kill zebra mussels or prevent settlement.

Recreation-based industries along Lake Erie have been impacted by zebra mussels. Unprotected docks, breakwalls, boat bottoms, and engine outdrives were rapidly colonized beginning in 1989. Consequently, there were numerous reports of boat engines overheating due to colonies of zebra mussels clogging cooling water inlets and mussels colonizing boat hulls.²

Beaches are also affected by zebra mussels. The sharp-edged mussel shells along swimming beaches can be a hazard to unprotected feet. By autumn of 1989, extensive deposits of zebra mussel shells were on many Lake Erie beaches. The extent of these deposits varied with successive periods of high wave activity.

Zebra mussel control

Lake-wide control of zebra mussels is not feasible. The European community, after two centuries of infestation, and the Great Lakes community, after years of infestation, haven't been able to develop a chemical toxicant for lake-wide control that isn't deadly to other aquatic life forms.

In some parts of Europe, large populations of diving ducks have actually changed their migration patterns in order to forage on beds of zebra mussels. The most extreme case occurred on Germany's Rhine River. Overwintering diving ducks and coots consumed up to 97 percent of the standing crop of mussels each year. High mussel reproduction rates, however, replenished the population each summer.

In North America, the species most likely to prey on relatively deep beds of zebra mussels are scaup, canvasbacks, and old squaws. But populations of these species are quite low; in fact, canvasbacks are so rare that they are protected. In the Great Lakes, diving ducks are migrating visitors, pausing only to feed during north- and southward migrations. However, Canadian researchers have documented increasing numbers of migrating ducks around Pt. Pelee in western Lake Erie, and these ducks were observed to be feeding heartily on zebra mussels. In southern Lake Michigan, zebra mussels encrusting an underwater power plant intake attracted flocks of lesser scaup. Unfortunately, some were pulled into the intake pipe and drowned. The stomachs of these dead scaup were full of zebra mussels. Mallard ducks also are frequently observed foraging on zebra mussels on shoreline rocks and shallow structures. In addition, freshwater drum, or sheepshead, are known to feed substantially on zebra mussels; and yellow perch have been observed feeding on juveniles, particularly when they are detached and drifting.

One novel approach to controlling zebra mussel populations is by disrupting the reproductive process. Zebra mussel eggs are fertilized externally; therefore, males and females must release their gametes (sperm and eggs) simultaneously. After release, zebra mussel sperm remain viable for only a short time—perhaps only a few minutes. Disrupting the synchronization of spawning by males and females may effectively reduce the numbers of fertilized eggs. Researchers are currently studying the environmental cues and physiological pathways that coordinate zebra mussel spawning activity.

Spread to inland waters

Zebra mussels can spread to other inland waters either as veligers transported in water or as adults attached to boat hulls, engines, aquatic weeds, or other surfaces. Veligers are small—about the size of the period at the end of this sentence—and may be able to survive in any residual water source.

Adult mussels are very hardy and can survive out of water for extended periods depending upon temperature, humidity, wind, and sunlight. Maximum out-of-water survival time in ideal conditions is about 10 days for adults and 3 days for newly-settled juveniles.

Based on a survey of boat users in Michigan, Dr. Ladd Johnson recommends the following to prevent further spread of zebra mussels:

- Remove any visible vegetation from items that were in the water, including the boat, trailer, and all equipment.
- Flush engine cooling system, live wells, and bilge with tap water. If possible, use hot water.
- Do not re-use bait if exposed to infested waters.
- Dry boat and other equipment for at least 48 hours before using in uninfested waters.
- Examine boat exterior for mussels if it has been docked in infested waters; if mussels are found or exterior is heavily fouled by algae, either clean fouled surfaces or leave boat out of the water for at least 5 days before entering uninfested waters.

Be advised that these recommendations are still being studied by researchers and resource managers.

Tests show that mussels will die if they are exposed to water hotter than 110F (40 C) for more than 15 minutes or to freezing temperatures (0F or -18 C) for more than 24 hours.

In earlier versions of this publication, chlorine disinfection was suggested but is no longer recommended since chlorine is toxic to other organisms and may also damage boat equipment. Salt water mixtures are also not recommended.

Veligers may be transported easily in water used in live bait containers. Minnows or crayfish used in lakes containing zebra mussels should be transferred to well water or aged chlorinated tap water before carrying them to other bodies of water.

Waterfowl and other wildlife may transport zebra mussels, carrying veligers and/or adults in wet fur or feathers.

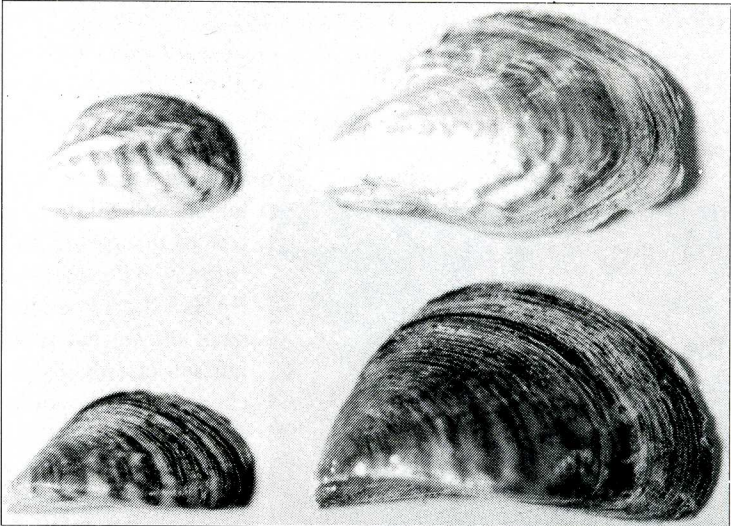
The zebra mussel is now a permanent part of the Great Lakes, many major river systems, and inland lakes; and it continues to spread rapidly

throughout major river basins. Increased support for research is needed to gain understanding of its natural predators, spawning activity, and pollutant uptake, as well as its effects upon ecosystems, industries, and local economies.

Theoretically, zebra mussel populations should peak a few years after initial infestation and then decline, depending upon predation and upon each water body’s carrying capacity. There is little doubt that the zebra mussel’s impact will be felt by everyone who uses our nation’s inland waters.

1 For more information on this issue, request a copy of Ohio Sea Grant’s fact sheet titled *Zebra mussel migration to inland lakes and reservoirs: A guide for lake managers* (OHSU-FS-058).

2 For more information on this issue, request a copy of Ohio Sea Grant’s fact sheet titled *Slow the spread of zebra mussels and protect your boat and other equipment, too* (OHSU-FS-054).



The quagga mussel (*Dreissena sp.*) above, and zebra mussel (*Dreissena polymorpha*) below.

Zebra mussels and Quagga mussels

Zebra mussels (*Dreissena polymorpha*) were accidentally introduced into the Great Lakes in the mid-1980s. Quagga mussels (*Dreissena bugensis*), an East European relative of the zebra, was found in the colder depths of Lake Ontario in 1991, across the bottom of Lake Erie in 1992, and in Saginaw Bay in Lake Huron. This table contrasts the characteristics of the two species.

| | ZEBRA MUSSELS | QUAGGA MUSSELS |
|--------------------------|--|---|
| Shell | Triangular shape Obvious ridge between side and bottom Sides merge with bottom Byssal (ventral) side flat | Rounder sides Ridge lacking Byssal side rounded |
| Color | Variable colors and patterns Usually dark | Pale near hinge Dark concentric rings on the shell |
| Byssal | Large groove in middle of flat side; allows tight hold on rocks | Small byssal groove near the hinge |
| Depth in Lake | 3 to 98 feet (1-30 m) Maximum 33 feet (10 m); rare below 50 feet (15 m.) | 3 to 351 feet (1-107 m) Commonly found down to 98 feet (30 m.) |
| Temperature | 32 to 86 F (0 to 30 C) | 32 to 86 F (0 to 30 C) |
| Tolerance | 54 to 68 F (12 to 20 C) preferred | 39 to 68 F (4 to 20 C) preferred |
| Reproductive Temperature | Young present at 57 to 68 F (14 to 20 C) | Young present as low as 46 F (8 C) |
| Growth | Up to 1 inch (25 mm)/year | Up to 0.8 inch (20 mm)/year |